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# Automated Test Equipment for the 1MT-172 Piston Actuator

by John P. Carpenter

U.S. Army Electronics Research and Development Command
**Harry Diamond Laboratories**
Adelphi, MD 20783

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An automated tester for the 1MT-172 piston actuator has been developed. The actuator is an electroexplosive device that, when electrically initiated, extends a piston. This actuator is used in several safety and arming devices developed by the Army. The project, funded by Manufacturing Testing Technology (MTT) funds, was sponsored by the Army Materials and Mechanics Research Center (AMMRC). The output of the automated tester is the piston-force-versus-stroke-displacement curve for the actuator. This tester also makes GO/NO-GO decisions based on peak force values and computes the total energy output. A hard-copy record is available from a self-contained plotter.

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CONTENTS



FIGURES

## SUMMARY

An automated tester for the 1MT-172 piston actuator has been developed. The actuator is an electroexplosive device that, when electrically initiated, extends a piston. This actuator is used in several safety and arming devices developed by the Army. The project was funded by Manufacturing Testing Technology funds and sponsored by the Army Materials and Mechanics Research Center. The output of the automated tester is the piston-force-versus-displacement curve for the actuator. This tester also makes accept/reject decisions based on peak force values and computes the total energy output. A hard-copy record is available from a self-contained plotter.

As a result of this project, actuator samples can now be evaluated more rapidly and more accurately than previously possible. Screening of production samples can be made with a much higher degree of precision and confidence. This screening will yield a decreased risk of fuze failures due to poor actuator performance and thus provide potential savings of many times the project's cost. In addition, the new test technique yields design and performance information, not otherwise obtainable, of significant value to the development effort or new fuze systems.

## 1. INTRODUCTION

Harry Diamond Laboratories (HDL) was funded by the Army Materials and Mechanics Research Center (AMMRC) to develop a testing device for the 1MT-172 piston actuator. This actuator is used in the SEAGNAT fuze, the Multiple Launch Rocket System (MLRS) fuze, and the shoulder-launched multipurpose assault weapon (SMAW) fuze, all developed by HDL. The amount of funding was $85,000. The piston actuator is a small (0.62 in.* long × 0.135 in. diam) electroexplosive device that rapidly extends a piston when approximately 5 mg of propellant is initiated by sufficient electrical energy (see fig. 1). The tester was to safely initiate the actuator, measure the piston's acceleration, and then compute and plot the output force versus the displacement of the piston. Peak force, pulse duration, and total energy developed were also to be recorded.

The tester was to be a stand-alone automated device requiring only low operator skill. Operator safety and near real-time analysis were also design requirements. The general components of the device were to be a fixture for holding the actuator, an accelerometer and signal conditioners for obtaining the acceleration pulse, and a microprocessor for computing and plotting the output information. The development was to result in a piece of test equipment that could be used in a production environment to run first article and lot acceptance tests (see fig. 2).

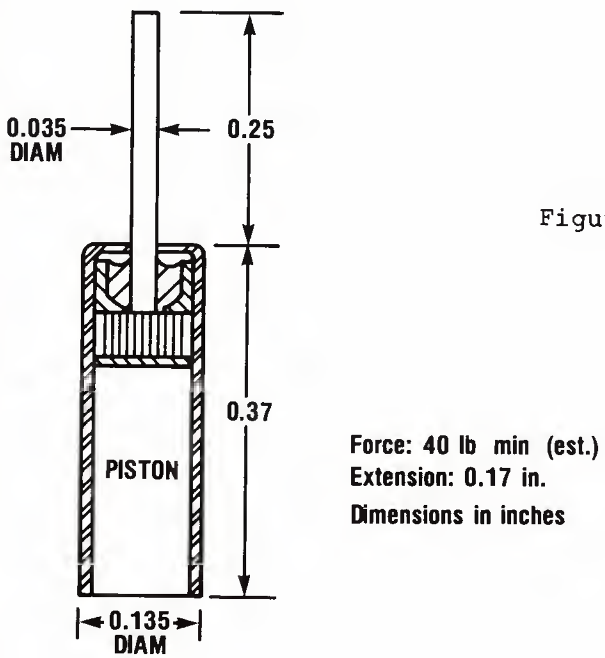


Figure 1. Electroexplosive piston actuator.

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*in.(2.54) = cm.

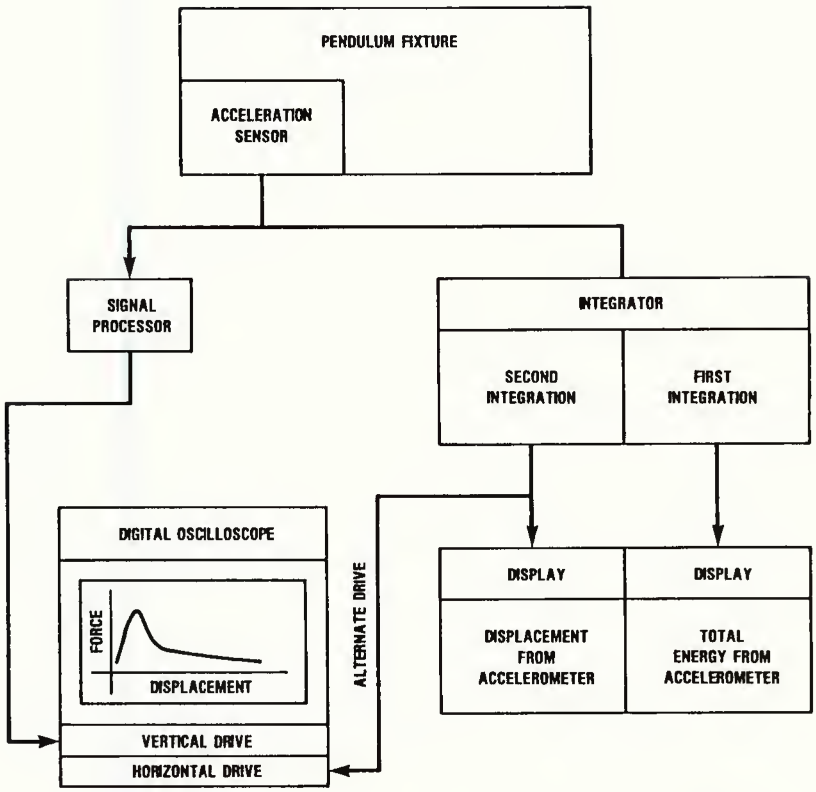



Figure 2. Piston actuator tester block diagram.

The project was considered a low development risk because HDL had previously obtained similar data in a laboratory environment. In that effort, piston actuators were used to fire accelerometers into the air. The pulses were recorded on magnetic tape and sent out of HDL for analysis plotting (see fig. 3). Plots were obtained for acceleration versus time directly, and for velocity and displacement versus time by integration of the acceleration curve. Since the mass of the accelerometer was known, the acceleration plot could be scaled to obtain force versus time. The force-versus-time and displacement-versus-time plots were hand digitized at simultaneous time points to obtain a plot of force versus displacement. The new tester was to perform the same operations but essentially in real-time operation.

The prior method of testing piston actuators is outdated and misleading. The actuators are tested by initiating the actuator, letting the piston cross a gap, and then recording the impact force the piston exerts against a load cell (see fig. 4). This may be a good test of the piston actuator's ability to excite an impact transducer, but piston actuators are not used in an impact mode in HDL fuzes. Typically, the piston actuator is used to remove a mechanical lock on an explosive train interrupter. The locks are usually staked in place and must be moved out of the way, using a high initial force to break the stake. Low-level continuing force is needed to move the lock. The force-versus-displacement data computed by the new tester show the shape of the force output curve whereas the old method only shows the total energy output. An actuator that has a low peak force but a high continuing force may be inadequate for breaking the stake on a mechanical lock; however, when tested with the old equipment, it appears the same as an adequate actuator.

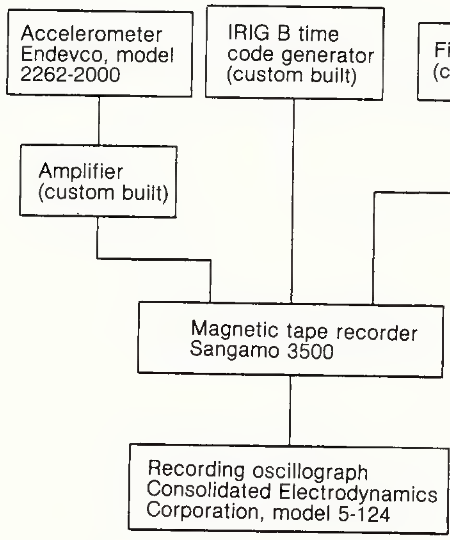



Figure 3. NAVSWC/WO instrumentation for piston actuator tests (May 1979).

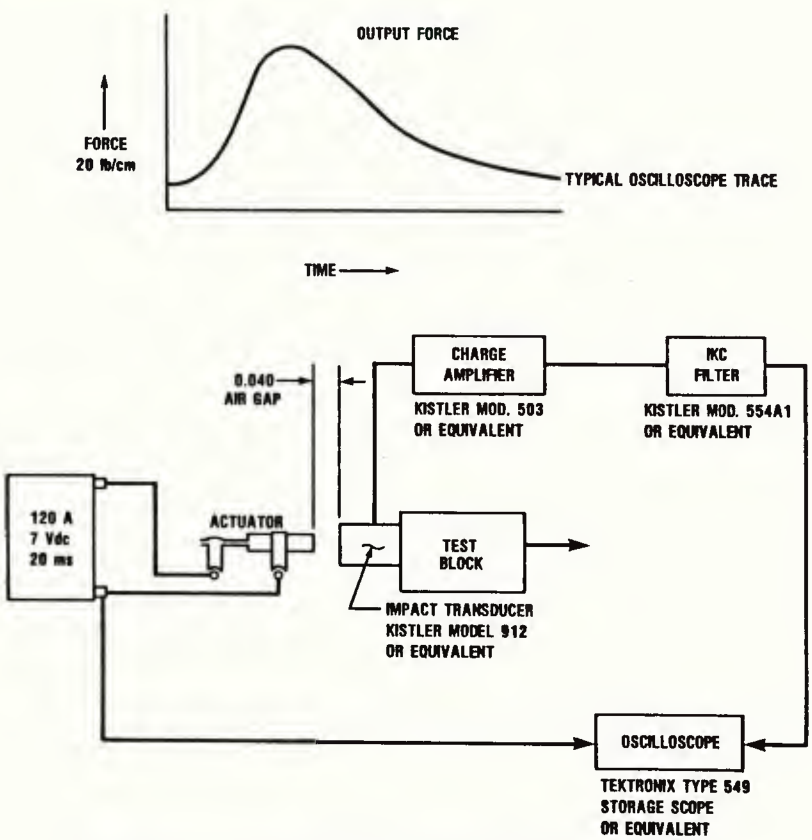



Figure 4. Function test instrumentation.

## 2. TESTER DEVELOPMENT

The test device had to be able to compute or sense directly the force output of the piston actuator. This could be performed by using a load cell for direct sensing or by using an accelerometer and computing the force by scaling the pulse. Since the load cell proved difficult to mount and the acceleration pulse can be integrated to obtain velocity and displacement data, an accelerometer was used. The load cell pulse could be scaled also. The previous investigation used an Endevco 2262-2000 piezoresistive viscous damped accelerometer. This accelerometer was obsolete when the new development began. A similar device, the Endevco 2262C-2000, half as sensitive, was available and was purchased. Laboratory tests on this device showed that the replacement accelerometer was not sensitive enough for this application. Endevco piezoelectric accelerometers were considered as a replacement. These accelerometers require a charge amplifier and are sensitive to cable whip between the accelerometer and the charge amplifier. PCB Piezotronics, Inc. makes a piezoelectric accelerometer, the 305A04, that has a self-contained charge amplifier. There is no problem with cable whip, and the device had the proper sensitivity. This accelerometer was purchased and used as a replacement for the Endevco 2262-2000 (see app A).

The output of the piston actuator was used to accelerate the acceleration transducer. To prevent damage, the transducer must be restrained. Both linear and rotational restraint methods were considered. A linear system simplifies the modeling of the device and its calibration. Such a system might consist of an actuator holder, the accelerometer transducer, and a tube to guide and catch the accelerated transducer. The disadvantage of the linear method is that the cable must travel along the path of the accelerometer. This causes the cable to flex and might lead to early failure. A rotational system is more difficult to model and calibrate but the cable can be better protected. This system would consist of an accelerometer mounted on the end of a pendulum arm. The piston actuator would be used to swing the pendulum arm. In this system the cable can be tied to the arm and does not flex. Thus, the rotational system was chosen for the tester (see fig. 5).

The PCB accelerometer is not a mechanically damped transducer. Signal conditioning was necessary to eliminate ringing in the accelerometer pulse. Laboratory instrumentation filters were used until the proper filter characteristics were determined. A custom filter was then built to match these characteristics.


Figure 5. Pendulum arm.

The force-versus-displacement curve was to be computed from the acceleration-versus-time curve and its second integral, the displacement-versus-time curve. The signal processing equipment was to be able to digitize the filtered accelerometer pulse, integrate and scale the curves, find parameter values such as peak force, and provide a hard-copy record. Several pieces of microprocessor-based equipment were evaluated. The Tektronix 8664 oscilloscope could do all the required operations but provided no hard copy. A microprocessor and plotter had to be added to obtain hard copy. This addition required interfacing the components with two microprocessors, one in the scope and one in the controller. The next system evaluated was a Nicolet Explorer III oscilloscope tied to a controller and plotter. This was simpler than the Tektronix and it permits statistical analysis of the data, but it still required custom interfacing of the components. T. G. Branden, Inc. offered a measurement system, "Smartscope," that required no interfacing and came complete with all the necessary system software. The system consisted of a controller/digitizer, a video monitor, a disk drive, and a plotter. All system functions were programmable and the equipment was low cost. This measurement system was purchased (see app B).

Integration of the test system concerned itself with three areas: system input, system output, and the interface between the operator and the system. Input data consisted of the acceleration pulse, calibration data, scope setup, tester programming, and reference values for attribute testing. The acceleration pulse came through the signal conditioning filter, and the calibration method was determined at the end of the tester development effort. Scope setup and tester programming was set up to occur automatically when the tester power was turned on (see app C). The reference values for attributes are contained in the software and are not normally accessible to the operator. These values can be changed, when the tester program is loaded, by anyone who knows the program protect code.

System output includes the hard-copy, force-versus-displacement plot, parameter values recorded on the hard-copy plot, a video display of the hard-copy material, and the video display of attribute tests. Data display is automatic and requires no operator action.

The operator would be required to perform a minimum of actions. Ideally, only loading the actuator and initiating the test sequence by the press of a button would be necessary (see app D).

The piston actuator test (PAT) system is physically composed of a fixture, a firing circuit console, the PCB accelerometer, an instrumentation filter, and the T. G. Branden Smartscope. The fixture has three main components: the support and pendulum arm assembly which holds the accelerometer, the piston actuator holder, and the enclosure. The enclosure, made of 5/8-in. plexiglass, protects the operator and observers from the piston actuators (see fig. 6).

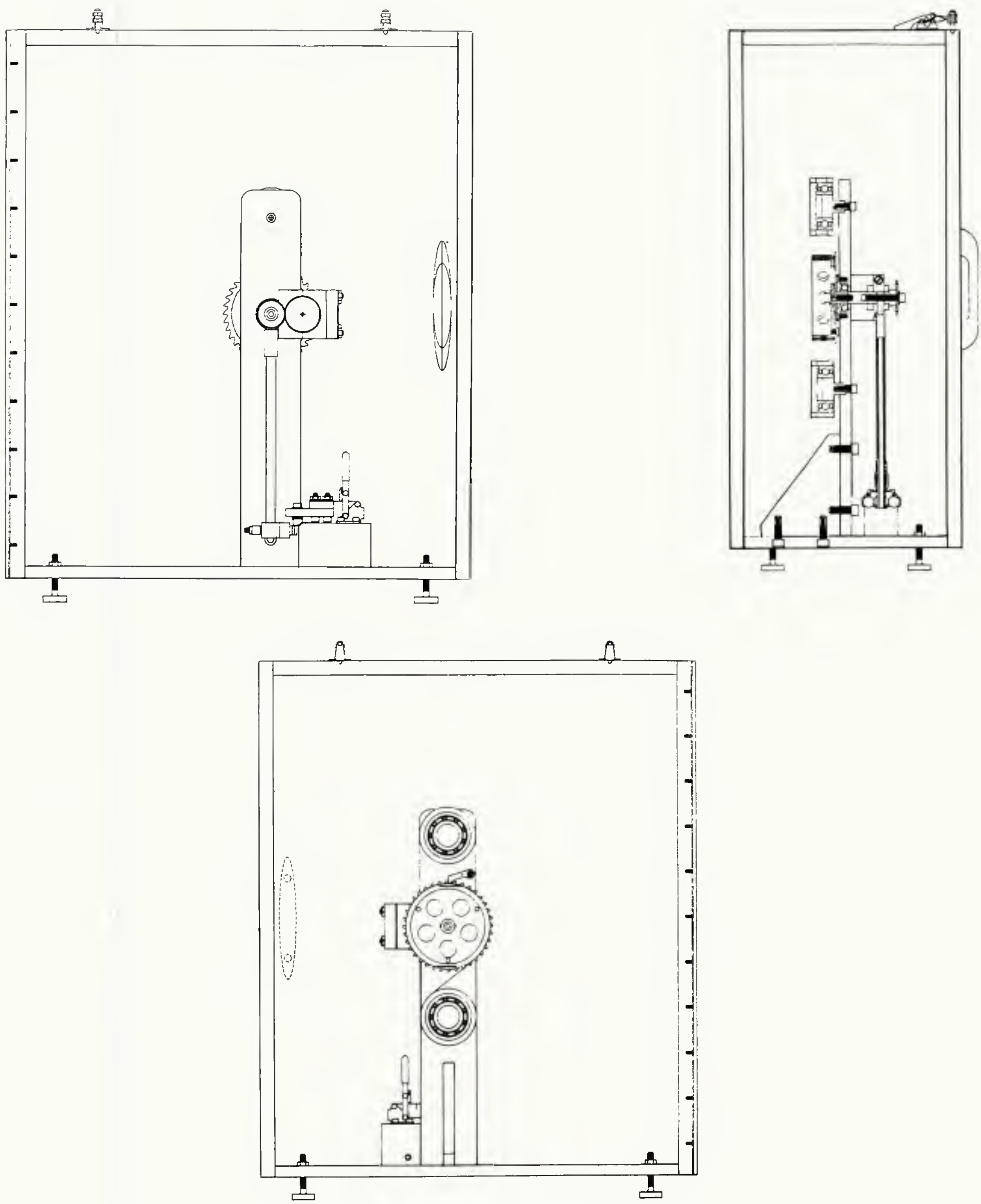


Figure 6.  Test fixture: (a) front view, (b) side view, (c) back view.

To start and operate the system, the operator loads the tester floppy disk into the disk drive. Power is turned on. The tester program and scope setup are loaded automatically by Smartscope's microprocesser. The operator then ensures that the firing circuit is set to the safe position and loads the piston actuator into the fixture. The operator then pushes the "RUN" button on the scope controller. The video monitor notifies the operator when to fire the actuator. The actuator is fired by setting the firing circuit to the armed position and pushing the fire button. The only remaining task for the operator is to load paper into the plotter if a hard copy record is desired. The microprocessor takes the acceleration pulse and scales it to obtain "g's." It then integrates this signal to obtain the velocity-versus-time curve. The velocity curve is used to compute the total energy parameter. The velocity curve is then integrated to obtain the displacement-versus-time curve. At this point the processor recalls the "g"-versus-time curve and scales this curve to get the force-versus-time curve. The computer determines the maximum and minimum force values. The maximum force is checked against a reference value. If the value is inadequate a message appears on the video to that effect. The amplitudes of the force versus time and the displacement versus time are plotted against each other. This gives the force-versus-displacement plot required by the system specification. A hard-copy record of the plot, the maximum and minimum force, and the total energy are available by selecting "PLOT" from the scope controller (see fig. 7).

The system required optimization of the the custom filter, the pendulum arm, and the accelerometer mount. Several design iterations were required on all three items before satisfactory results were obtained. The final filter schematic is shown in figure 8.

The system was calibrated by using an energy method. The pendulum arm has a wind-up spring device that stores the energy imparted to it by the actuator. The potential energy stored in the arm by a pulse can be compared to the kinetic energy that the pulse gives to the arm. This comparison determines the effective inertia of the system. The inertia value is used to scale acceleration measurements to get force values. An initial inertia value was assumed and then modified to fit the experimental data.

The inertia was assumed to be $I = mr^2$, where m is the mass of the accelerometer at the end of the pendulum plus one-third the mass of the pendulum rod, and r is the radius at which the accelerometer is mounted. This mass was 37.56 g. The radius is 9 in. The resulting inertia estimate is $Ie = 0.01736$ lb-s$^2$-in. The energy represented by spring wind-up is given by $Ep = T0$, where Ep is the potential energy stored, T is the torque applied, and 0 is the rotation of the pendulum in radians if torque is constant. The pendulum spring used is a constant torque-negator-type spring, and the torque is very nearly constant in the 0 range used (see fig. 9). The pendulum is mounted on ball bearings, so friction loss is minimized. The energy put into the system for the calibration was equal to 11.46 in.-lb. The potential energy stored by the spring should be equal to the kinetic energy that the arm has prior to spring wind up. This energy is given by $Ek = (1/2)Iw^2$, where Ek is the kinetic energy, I is the inertia, and w is the rotational velocity of the pendulum arm; w is equal to XD/r where XD is the tangential velocity of the

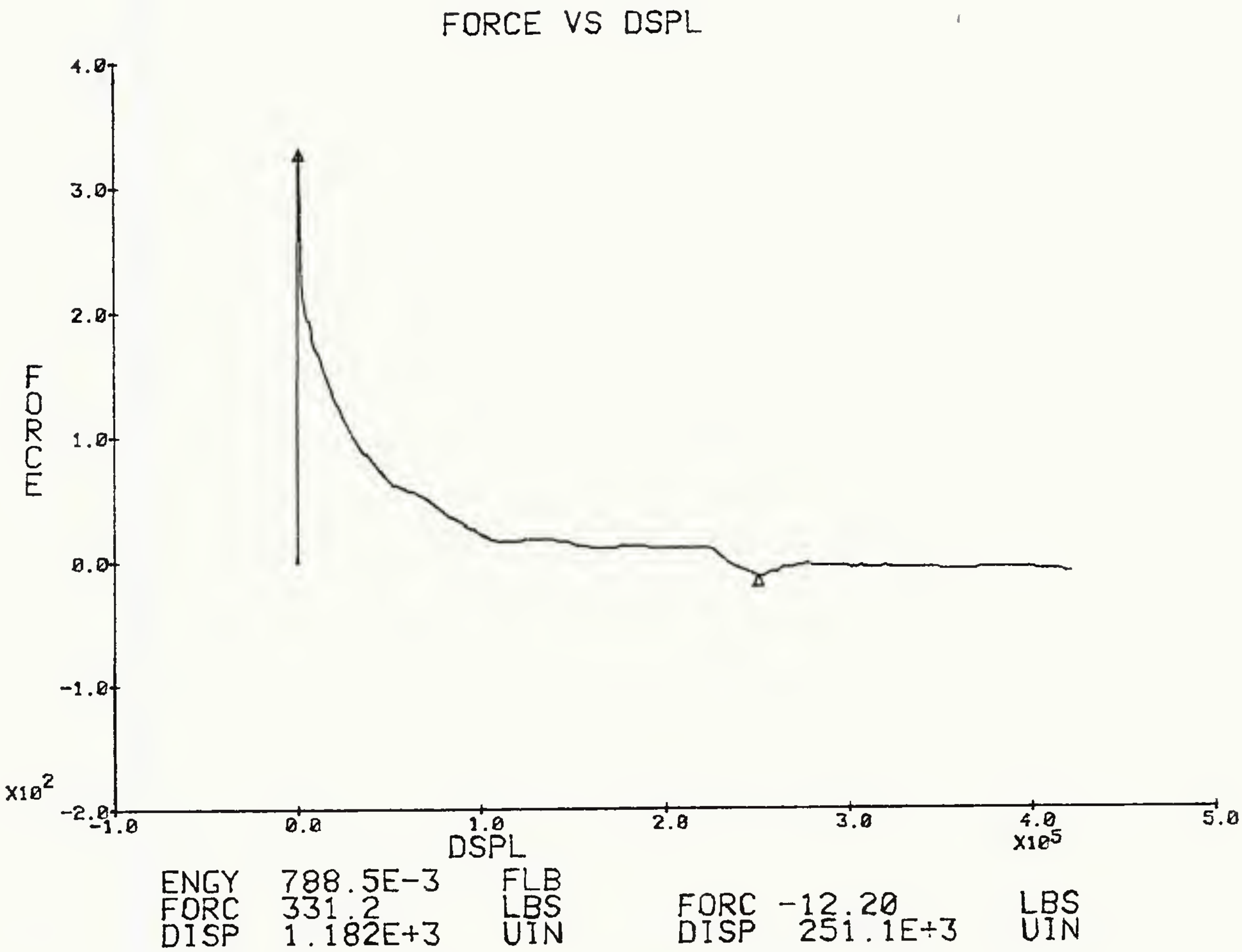
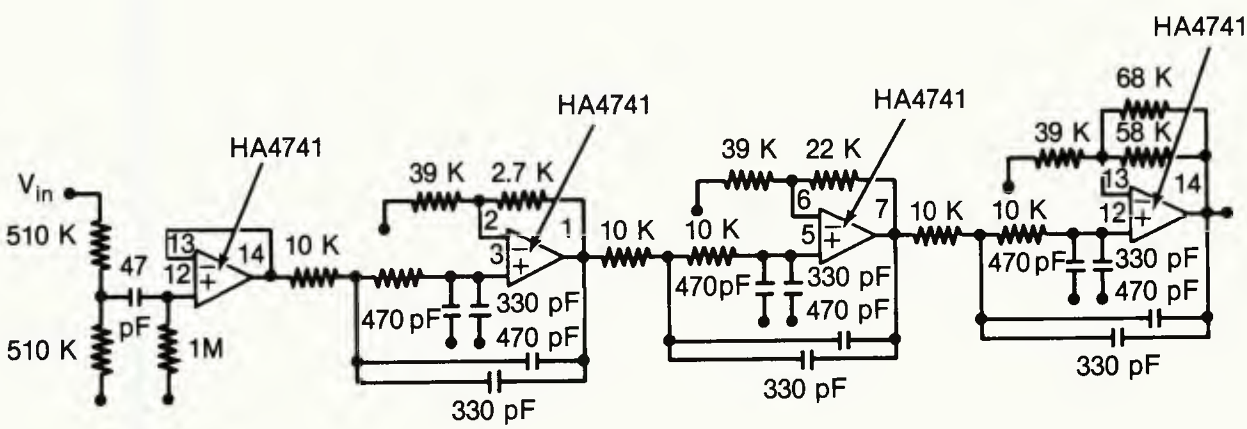



Figure 7. Sample hard-copy output.




Notes:
1. Connect pin 4 of HA4741 to +10 V.
   Connect pin 11 of HA4741 to −10 V.
2. FMB 10 kHz.

Figure 8. Six-pole active low-pass filter.

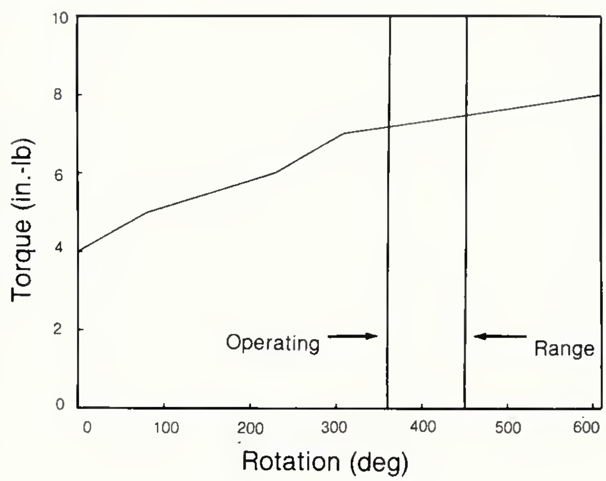



Figure 9. Torque versus rotation, PAT return spring.

pendulum arm. A calibrated accelerometer is used to obtain the change in this velocity over the stroke of the piston actuator. Since the initial velocity was zero, the final velocity is determined. This value was 297.22 in./s. If the estimated value for the inertia is correct, the potential and kinetic energy should be equal:

$$Ep = 11.46 \text{ in.-lb}$$

$$Ek = \frac{1}{2} Iw^2$$

$$= \frac{1}{2} I(XD/r)^2$$

$$= 0.5(0.01736)\ (297.22/9)^2$$

$$= 9.47 \text{ in.-lb.}$$

The ratio between the two energies is 11.46/9.47 or 1.21. This represents the error in the estimated inertia. The actual effective inertia can be computed using the following ratio: I actual = 0.01736 (1.21) = 0.02101 lb-s$^2$-in. Once the inertia has been determined the force for any value of acceleration can be calculated from the equation,

$$T = IODD \text{ and } ODD = XDD/r,$$
$$Fr = I\ XDD/r,$$
$$F = I\ XDD/r, \text{ and}$$
$$F = 0.0002594\ XDD,$$

where XDD is the tangential acceleration and ODD is the angular acceleration. This is the equation used to calculate the force-versus-time curve from the acceleration-versus-time curve in the piston actuator tester program.

The tester reliability and consistency were demonstrated by running a test of 100 actuators. No system problems were discovered in these tests. The tester has also been used as part of a first article test for piston actuators on SMAW's. The MLRS has used the tester to qualify a new piston actuator design. HDL is trying to develop alternative sources of supply for the actuators. The tester has been used to compare actuators from different manufacturers as part of this effort.

## 3. CONCLUSIONS

The piston actuator tester developed by HDL meets the design requirements established by the MTT program. A force-versus-displacement plot and parameter values are available on a video or hard-copy record. The video display is available 30 s after actuator initiation. This is a short enough time span to allow production testing of actuators. The tester makes GO/NO-GO decisions based on the parameter values. Operator skill required is low and the tester is self-contained.

## 4. RECOMMENDATIONS

Purchase specifications for piston actuators should be changed to include sample testing by testers of this type.

# APPENDIX A.-- ACCELEROMETER CHARACTERISTICS

(Courtesy of PCB Piezotronics, Inc.)

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LOW-IMPEDANCE, VOLTAGE-MODE

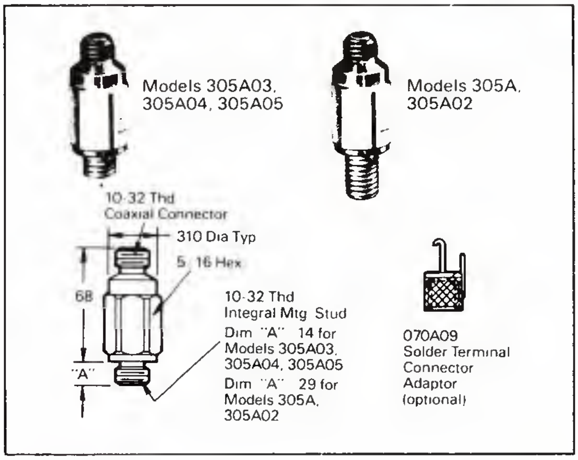
# HIGH-SHOCK ACCELEROMETER

with built-in amplifier

## Series 305A

PCB PIEZOTRONICS

MOTION shock & vibration




- rugged, light-weight, highly reliable design
- very high resonant frequency
- built-in amplifier - low impedance output
- no zero shift
- operates over long coaxial or 2-wire cables
- quality signal independent of cable motion or length

**For measurement of high amplitude pyrotechnic shocks associated with ballistic projectiles, metal to metal impacting, explosive forming, closed bombs and blast effects on structures.**

Model 305A quartz accelerometer measures mechanical shock motion to 100 000 g. Small size and light weight impart fast response (less than 10 microseconds) and assure a minimum effect on the structure of the test object. It follows transient events up to 0.1 second duration and generates a quality signal independent of cable length, condition and motion.

This miniature transducer with an integral mounting stud installs by threading into a tapped hole in the structure of the test object. For electrical connections in extreme shock environments, the optional solder pin connector adaptor and fine stranded ribbon wire (007A Cable Assembly) has proved more durable than coaxial components.

The rigid structure of this transducer contains a very small seismic mass preloaded against a quartz element by a thin walled sleeve, mechanically isolated from the outer case. A built-in unity-gain microelectronic amplifier lowers the output impedance and improves resolution by eliminating the cable capacitance effect on amplifier noise.

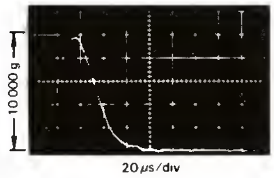
When connected to a PCB power unit, self-amplifying PCB transducers generate a high-level, low-impedance analog output signal proportional to the measurand and compatible with most readout instruments. Power is supplied over the signal lead.

| SPECIFICATIONS: Model No. | | 305A |
|---|---|---|
| Range, FS (5V output) | g | 100 000[1] |
| Resolution | g | 2.0 |
| Sensitivity | mV/g | 0.05 |
| Resonant Frequency (mounted) | Hz | 60 000 |
| Time Rise | μs | 5 |
| Discharge Time Constant | s | 2 |
| Frequency Response (±5%) | Hz | 0.25 to 8000 |
| Frequency Response (2.5dB) | Hz | 0.15 to 20 000 |
| Linearity | % | 1 |
| Overload Recovery | μs | 10 |
| Output Impedance | ohm | <100 |
| Transverse Sensitivity | % | 5 |
| Strain Sensitivity | g/μin/in | 0.2 |
| Temperature Coefficient | %/°F | 0.03 |
| Temperature Range | °F | -100 to +250 |
| Vibration/Shock (max transverse) | g | 75 000/30 000 |
| Weight | gm | 4.5 |
| Excitation/Constant Current | VDC/mA | -18 to +28/2 to 20 |
| **(1) Optional 5V Ranges** | | **Model No.** |
| 50 000 g 0.1 mV/g | | 305A02 |
| 10 000 g 0.5 mV/g | | 305A03 |
| 5000 g 1 mV/g | | 305A04 |
| 2500 g 2 mV/g | | 305A05 |
| Charge-Mode | 0.2 pC/g | 315B[2] |

(2) Larger Size (.47 Dia x .70 High)

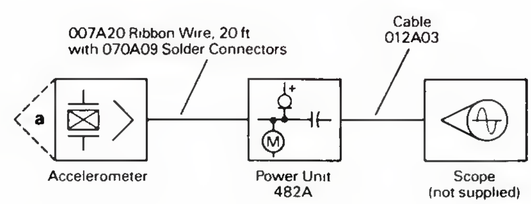
To specify metric Thd M5 x 0.8, add prefix "M" to model no. - e.g. M305A

### TYPICAL RESULTS




20 μs/div

### TYPICAL SYSTEM:

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# APPENDIX B.--SMARTSCOPE LITERATURE

(Excerpted from "SMARTSCOPE, Bringing Intelligence to Waveform Analysis," T. G. Branden Corporation, 1979)

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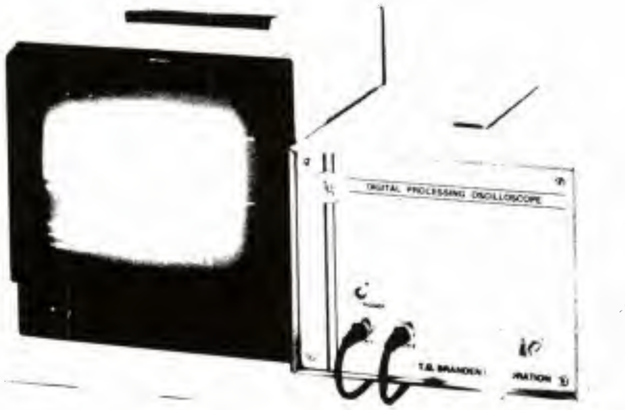
# The Hardware



very digital Processing Oscilloscope in the Smartscope series is a complete system for the acquisition, display, and processing of analog signals in the time domain. Designed around a 16 bit microprocessor and two or four 12 bit A to D converters, Smartscopes combine hardware with powerful software routines specifically designed

to handle waveforms. Whether your results are to be displayed and analyzed on screen, stored on disc, plotted or transmitted to a computer, Smartscopes are a cost-effective way.

Waveforms are displayed on a 9" (diag.) screen easily viewed even in brightly lit environments. "Loop through" video allows additional displays to be added as required.

Programmable to us means that all hardware except the power switch can be controlled by the software. All machine functions such as input sensitivity, sweep time, and trigger conditions are selected through a calculator style keypad. This same keypad is used for the manipulation and storage of acquired data.

An optional RS-232C input/output port provides for the transfer of waveform data, registers, machine set-up, messages, and programs. Transfer can occur from a Smartscope, computer, or terminal to a Smartscope, computer, or terminal. All transfers are in standard ASCII form.

An IEEE-488 option meets all requirements of the 1978 standard for a listener and talker. The same data transfer functions of RS-232C are provided with this option.

Hard copy of acquired waveforms, display annotations, and measurement read-outs is provided by a digital plotter. A fully annotated dual channel display takes no more than 3 minutes to plot. Plots are made on standard 8½ x 11" paper with pen and ink so no special paper is required.

Depending on the model chosen, 2 or 4 channels of data are acquired. The incoming analog data is converted to digital data simultaneously in all channels. This means no multiplexing of channel inputs and effectively no time skew between channels.

An external trigger input is provided as well as an internal connection to CH 1 only.

A continuously variable sweep delay allows display of times before and after the trigger event.

Up to 66 KHZ sample rate (15 us per point)
2 to 8 arrays for channel storage
Up to 4 arrays displayed
Variable memory length per channel (up to 10,000 data points single channel)
Four acquisition modes—manual, transient, repeated and an autorange that automatically seeks a correct amplitude range for each channel.
Input sensitivity from ± 100 mv to ± 20 volts
Choice of AC or DC coupling
X10 probe selection automatically adjusts readout
User selected Engineering units for calibration of both time and amplitude.
Number of arrays and channels dependent on model selected.

Make your transient recorder or sampling scope smarter. In most cases, the analog output from a transient recorder or sampling oscilloscope can be transferred to the Smartscope. All the processing and data handling power becomes available even though the

COPY

signal occurred too fast for the Smartscope to acquire directly. Our basic system price begins to make this a cost effective alternative. Contact us for more details and a specific recommendation for your equipment or application.

# The Software

Dual cursors, whose positions are independently controlled from the keypad can be moved to any point on a display. Digital readout of amplitude and time values are displayed and updated on screen each time a cursor location is changed. Cursor motion can be selected to move point to point, to seek a local maximum, to seek a local minimum, to go to a specified time location, or to seek a specified amplitude value.

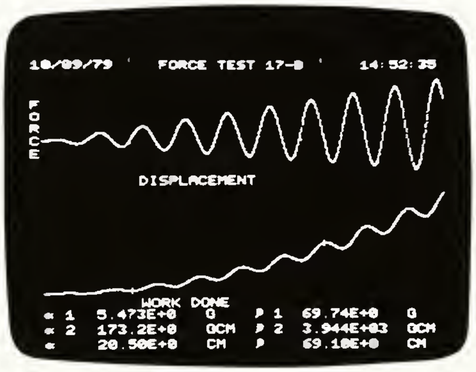
Array and register operators bring up powerful routines to process and manipulate waveforms and registers.

- Definite Operators — Operate on data between cursor settings resulting in a numeric value for Peak-Peak, RMS, Slope, Definite Integral, Area under the Curve, 1/Delta Time, Rise-Time and Mean.
- Array Operators — Operates on entire array to Differentiate, Integrate, Smooth, Data Shift and Data Rotate.
- Math Operators — Applies operators to make numeric modifications to arrays or registers or to apply a set of Transcendental operators (sine, cosine, arctangent, log, ln, square root or exponential) to arrays or registers.
- Inverse Definite Operators — The Inverse Definite Operator for Peak to Peak positions the cursors to the max and min points on a waveform.

Set up and review of machine conditions are accomplished from a single screen. The review screen displays the current settings of input sensitivities and coupling, sweep time and delay settings as well as trigger conditions. Using the keypad, a blinking cursor may be positioned to any of these conditions and a change made by use of editing keys.

A glance at the review screen gives a complete, easy to understand picture of machine state without having to interpret knob or variable control settings. A review screen for a two channel unit with fixed array length per channel is shown on the right.

Up to 8 arrays are available for storage and manipulation of acquired data. In some models, array length can be selected for up to a total of 10,000 data points.

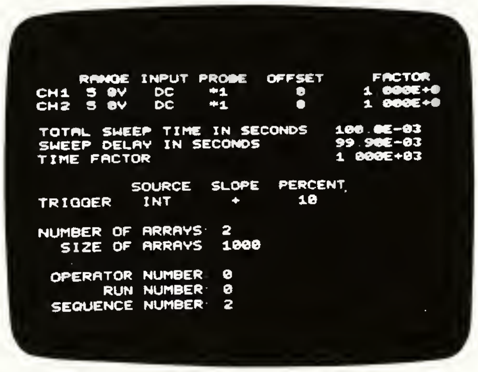



A choice of display formats allows up to four arrays to be displayed on screen at a time. Combinations are:

Array amplitude vs. time (up to 4 arrays).
Up to 4 arrays vs. another array.
Superposition of arrays on a common base line.
Expansion of a portion of the arrays horizontally and vertically.

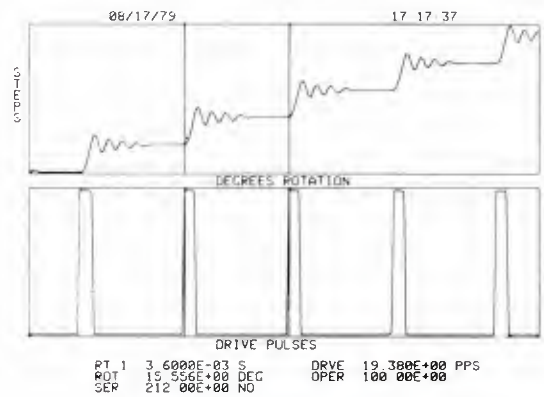
Displays may be fully annotated to represent the actual parameters you are working with. The horizontal or vertical axes may be labeled for clarity and the readout register label and units may be set to represent your measurement units. Date, title, and time of acquisition may be displayed to further document the measurement made. The digital plotter option will provide you a hard copy of what's on screen suitable for reports, engineering notebooks, test or quality assurance records. And the information may also be stored on floppy disc for later display or plot.

A keypad programming option allows you to create your own measurement programs in a manner similar to a programmable calculator. You select a learn mode and perform your measurement as you normally would. The Smartscope will remember the keystrokes you made, and perform that sequence each time the run button is pressed. Additional keys allow you to list your program, edit it, insert steps, delete steps, or store the



program on disc for later recall. Conditional branching, screen control, and choice of learn time or run time data entry are also available in addition to the normal operation of the machine. Whether your need is repetitive measurements, go-no-go testing, hard copy generation, disc storage, screen messages or data exchange through a RS-232C or GPIB port, all these operations and more can be done under program control.

A Model 700 Disc optional addition to the Smartscope provides storage and retrieval of: waveform data, machine set-up conditions and user applications programs. Storage space is dynamically allocated on the disc and files are addressed and listed on a directory by user created names. The directory shows the space remaining on a diskette for storage. Software file protect and error checking routines for soft and hard errors are built in. An additional option is available to allow a machine setup file to be automatically loaded from the disc on power-up. This is especially useful in a production environment. The media is commonly available 5¼" diskettes.




The Model 730 Digital Plotter option provides fully annotated hard copy of Smartscope displays. The plotter uses pen and ink to plot on standard 8½ x 11" paper. All required software is provided with this option. A reduced size reproduction of a Model 730 plot is shown on the right.

## APPENDIX C.--PAT PROGRAM LISTING

## PAT Program LISTING

```
1.  IDENTIFY
    4.  REGISTER LABELS, UNITS
        REGISTER 3-00
        REGISTER LABEL:  VEL
        REGISTER UNITS:  MPS
    4.  REGISTER LABELS, UNITS
        REGISTER:  3-01
        REGISTER LABEL:  VEL
        REGISTER UNITS:  MPS

    EXIT

2.  IDENTIFY
    4.  REGISTER LABELS, UNITS
        REGISTER:  3-13
        REGISTER LABEL:  TIME
        REGISTER UNITS:  MS
    4.  REGISTER LABELS,  UNITS
        REGISTER:  3-14
        REGISTER LABEL:  TIME

        REGISTER UNITS:  MS
    EXIT

3.  MESSAGE
    PISTON ACTUATOR TESTER

4.  PAUSE
    1.  TIMED PAUSE
        PAUSE LENGTH IN SECONDS

5.  MATH OPERATORS
    3.  CONSTANT
        CONSTANT

    5.  MOV
    1.  MEMORY CHAN
    MEMORY CHANNEL 3

6.  MATH OPERATORS
    3.  CONSTANT
        CONSTANT:  0
    5.  MOV
    1.  MEMORY CHAN
    MEMORY CHANNEL 1

7.  MATH OPERATORS
    3.  CONSTANT
        CONSTANT:  0

    5.  MOV
    1.  MEMORY CHAN
    MEMORY CHANNEL 4

8.  MESSAGE

    PLEASE WAIT 5 SECONDS AND

    FIRE THE PISTON ACTUATOR

9.  ACQUIRE

10.  DISPLAY
    1.  TIME
    MEMORY CHANNEL 1

    MEMORY CHANNEL 3

    MEMORY CHANNEL 4

    EXIT

11.  MAIN SCREEN ON/OFF
    1.  ON
```

12. MATH OPERATORS
    1. MEMORY CHAN
    MEMORY CHANNEL 1
    5. MOV
    MEMORY CHANNEL 3

13. MATH OPERATORS
    3. CONSTANT
       CONSTANT: 970.87
    3. MPY
    1. MEMORY CHAN
    MEMORY CHANNEL 3
    MEMORY CHANNEL 3

14. MEMORY CHANNEL OPERATORS
    2. INDEFINITE INTEGRAL
    MEMORY CHANNEL 3

15. MATH OPERATORS
    3. CONSTANT
       CONSTANT: 386.4
    3. MPV
    1. MEMORY CHAN
    MEMORY CHANNEL 3
    MEMORY CHANNEL 3

16. MATH. OPERATORS
    1. MEMORY CHAN
    MEMORY CHANNEL 3
    5. MOV
    MEMORY CHANNEL 4

17. MEMORY CHANNEL OPERATORS
    2. INDEFINITE INTEGRAL
    MEMORY CHANNEL 4

18. PAUSE
    1. TIMED PAUSE
       PAUSE LENGTH IN SECONDS

19. MAIN SCREEN ON/OFF
    2. OFF

20. IDENTIFY
    4. REGISTER LABELS, UNITS
       REGISTER: 1-00
       REGISTER LABEL: FORC
       REGISTER UNITS: LBS
    4. REGISTER LABELS, UNITS
       REGISTER: 1-01

       REGISTER LABELS: FORC
       REGISTER UNITS: LBS
    EXIT

21. MATH OPERATORS
    3. CONSTANT
       CONSTANT: 98.79
    3. MPY
    1. MEMORY CHAN
    MEMORY CHANNEL 1
    MEMORY CHANNEL 1

22. IDENTIFY
    3. MEMORY CHANNEL LABELS
    MEMORY CHANNEL 1
       VERTICAL LABEL: FORCE
       HORIZONTAL LABEL: TIME
    3. MEMORY CHANNEL LABELS
    MEMORY CHANNEL 4
       VERTICAL LABEL: DSPL
       HORIZONTAL LABEL: TIME
    5. TITLE

DISPLAY TITLE: FORCE VS
EXIT

23. IDENTIFY
    4. REGISTER LABELS, UNITS
       REGISTER: 4-00
       REGISTER LABEL: DISP
       REGISTER UNITS: UIN
    4. REGISTER LABELS, UNITS
       REGISTER: 4-01

28. CLEAR SCREEN

29. MESSAGE
    NOT ENOUGH POP TO IT

30. PAUSE
    1. TIMED PAUSE
       PAUSE LENGTH IN SECONDS

31. AAA:

32. CURSOR RESET

REGISTER LABEL: DISP
REGISTER UNITS: UIN
EXIT

24. DISPLAY
    2. MEMORY CHAN
    MEMORY CHANNEL 4
    MEMORY CHANNEL 1

    EXIT

33. HORIZ EXPAN

34. CURSOR RESET

35. INVERSE DEFINITE OPERATOR
    MEMORY CHANNEL 1

36. MATH OPERATORS
    3. CONSTANT
       CONSTANT: .000083333
    3. MPY
    3. REGISTER
       SECOND SOURCE REGISTER

25. CURSOR RESET

26. INVERSE DEFINITE OPERATORS
    MEMORY CHANNEL 1

27. CONDITIONAL
    2. REGISTER
       REGISTER NAME 1-00
    5. GREATER THAN
    1. CONSTANT
       CONSTANT 100
       LABEL AAA

DESTINATION REGISTER: 00

37. MATH OPERATORS
    2. REGISTER
       REGISTER: 00
    3. MPY
    2. REGISTER
       SECOND SOURCE REGISTER:

    DESTINATION REGISTER: 00

38. MATH OPERATORS
    3. CONSTANT
       CONSTANT: .0015806
    3. MPY
    2. REGISTER
       SECOND SOURCE REGISTER:

    DESTINATION REGISTER: 00

39. MATH OPERATORS
    3. CONSTANT
       CONSTANT: 0

    3. MPY
    1. MEMORY CHAN
    MEMORY CHANNEL 8
    MEMORY CHANNEL 8

40. MATH OPERATORS
    3. CONSTANT
       CONSTANT: EXIT

41. MATH OPERATORS
    2. REGISTER
       REGISTER: 00
    1. ADD

       MEMORY CHAN
    1. MEMORY CHAN
    MEMORY CHANNEL 8
    MEMORY CHANNEL 8

42. IDENTIFY
    4. REGISTER LABELS, UNITS
       REGISTER: 8-01
       REGISTER LABEL: ENGY
       REGISTER UNITS: FLB
    7. SELECTED REGISTERS

POSITION 1: -
POSITION 2: -
POSITION 3: -
POSITION 4: -
POSITION 5: - 8-01
POSITION 6: -
POSITION 7: EXIT

43. PROGRAM END

SCOPE SET-UP PARAMETERS

| | RANGE | INPUT | PROBE | OFFSET | FACTOR |
|---|---|---|---|---|---|
| CH1 | 10.V | AC | #1 | 0 | 850.0E- |
| CH2 | 5.0V | AC | #1 | 0 | 1.000 |

ACQUISITION MODE TRANSIENT
TOTAL SWEEP TIME IN SECONDS 2.000E-3
POST TRIGGER DISPLAY IN SECONDS 1.800E-3
TIME FACTOR 1.000E+3 OFFSET 0

| | SOURCE | SLOPE | PERCENT |
|---|---|---|---|
| TRIGGER | CH1 | + | 10 |

NUMBER OF MEMORY CHANNELS 8
SIZE OF MEMORY CHANNELS 200

# APPENDIX D.--PAT OPERATOR'S MANUAL

## D-1. OPERATING SEQUENCE

This procedure covers the operating sequence for the piston actuator tester (PAT). It consists of a step-by-step procedure, a list of operator-correctable problems and cures, and the scope setup values.

### D-1.1. Startup Operation

The tester programming and oscilloscope setup values are stored on an 8-in. floppy program disk. This disk must be inserted into the disk drive before power is applied to the oscilloscope body. First, turn on the power to the plotter, the video monitor, and the disk drive. Insert the program disk into the drive. The disk is inserted with the label on top and the oval cutout toward the disk drive. Next, turn on the power to the scope mainframe. The program and scope setup values will be loaded automatically. When the red light on the disk drive goes out, the program has been loaded. The video display will show the scope name and manufacturer. Next, turn power to the firing circuit and the transducer ON. The transducer needle display should be in the green area. Firing circuit voltage is operator-selectable, but is usually 25 V. Make sure the firing circuit controls are OFF and the arming switch is in the SAFE position. The tester is now ready for loading.

### D-1.2. Loading the Piston Actuator

Follow local safety procedures for handling electroexplosive devices. Insert a piston actuator into the copper body clip. Put the assembly into the actuator cylinder. The cylinder should then be loaded into the holding fixture located at the base of the pendulum support. An overcenter clamp is used to secure the cylinder in place. Release the pendulum ratchet and set the pendulum arm against the piston actuator. Close and secure the enclosure door. Switch the arming switch to the ARMED position and check the resistance of the actuator. This resistance reading can be obtained from the two yellow terminals on the firing panel. The device must be checked with a low-current ohm meter. Do not apply more than 2 mA to the piston actuator through the yellow terminals. Switch the arming switch to the SAFE position. Turn the firing circuit ON. Set the arming switch to the ARMED position. The piston actuator is now ready to fire.

### D-1.3. Running a Test Sequence

The scope mainframe has a control board attached to it by a length of flex cable. In the lower right-hand side of the board is a button marked R/S. When the button is pushed, the test sequence begins. The video display will ask the operator to fire the piston actuator. This is done by pressing the red firing button on the firing circuit panel. The tester will then display a number of curves. If the force output of the actuator is too low, the video display will have a message to that effect. After a short period the words PROGRAM END will be displayed and the force versus displacement curve will be shown. The operator should then turn the firing circuit off and set the arming switch to the SAFE position.

### D-1.4 Hard-Copy Records

The program for plotting the video display is not automatically loaded into the computer. It must be manually loaded by the operator. The loading is done via the scope mainframe control board. The loading operation does not erase the video display or the tester program. The sequence used to load the plot program is shown below: Lower-case notations represent responses made by the computer on the video screen. Upper-case and numerical notations represent the operator's input. The input consists of pushing the scope control-board button indicated:

Op--DISK
Cm--menu (the computer lists a menu of selections)
Op--No. 8 (options)
Cm--menu (which option?)
Op--No. 2 (plotter)
Cm--menu (load or save?)
Op--No. 1 (load)
Cm--no change--the computer is loading the plot program. When the loading operation is finished the video display will be returned and plots can be made.

The plot is obtained by pushing the button on the scope control board marked PLOT. The computer will ask the operator to input the number 1 if the plotter pen is in the lower left-hand position. When the number is entered, the plot is started. At the end of the plotting sequence, the video display is returned. Once the plot routine has been loaded it will stay in the microprocessor memory until the power is turned off.

## D-2. TROUBLE SHOOTING

| Problem | Fix |
|---|---|
| 1. Program stops in mid-execution | Press R/S button--program may continue. If not, press reset on scope. Data will be lost but program may reset. Last resort is to switch scope body off and then on again. Program will autoload and you can begin again. |
| 2. Program does not respond to firing of piston actuator | Sensitivity is too low. Press SETUP button and change the voltage scale for channel one to a lower value. |
| 3. Plotter action erratic | Reload plot program. Data are not lost during this process. |

| | |
|---|---|
| 4. Scope does not autoload program correctly | Shut off power and restart tester. If this fails the disk may be bad. Use spare disk. |
| 5. Scope traces are off scale | Sensitivity may be too high. Correct as in No. 2. Accelerometer cables or accelerometer may be loose. Tighten them. |
| 6. Miscellaneous | The last resort of any fix is to shut off the power and restart the tester. |

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